The Coupled Oceanographic-Tomographic Analysis and Prediction System

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LONG-TERM GOALS

Research and development the various technologies for transitioning high-frequency ocean tomography into practical use by utilizing acoustic travel time data to improve ocean circulation model predictions.

OBJECTIVES

Our objectives are to investigate all facets related to performing high-frequency (> 3 kHz) acoustic tomography in an open-ocean environment and assimilating the tomographic data into dynamic, primitive equation, ocean models to improve the spatial and temporal predictions of temperature (T), salinity (S), and sound speed profiles (SSP's). We have concentrated on enhanced processing of matched filter results for determining travel times and modeling multi-path arrivals for ray paths striking the ocean surface.

APPROACH

Under funding from the Center of Excellence for Research in Ocean Sciences (CEROS), an Acoustic Data Acquisition System (ADAS) was developed. This is an automated system to interface with a Navy range's source-receiver control system, specify which sources and receivers to activate, and process the receiver data to calculate travel times. This is one of the basic components of the Coupled Oceanographic-Tomographic Analysis and Prediction System (COTAPS).

Partially in support of the CEROS work, our ONR work concentrated on characterizations of the multipaths that result from ocean waves at the air-sea interface. These studies provided insights into the causes and the nature of multipath signatures observed in matched filter results. The results of the work were used to develop enhanced processing techniques of matched filter results, and these techniques were programmed into the ADAS for the CEROS work.

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14. ABSTRACT

Research and development the various technologies for transitioning high-frequency ocean tomography into practical use by utilizing acoustic travel time data to improve ocean circulation model predictions.

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Dr. James K. Lewis was the primary individual working on the task related to developing enhanced processing techniques of matched filter results. He also worked on the multi-path modeling studies.

WORK COMPLETED

An initial model study was conducted to better understand the impact of surface waves on ray paths from an omni-directional source. The results were published in Lewis, 2008 (*J. Acoust. Soc. Am.*, 123(2), 878-886). The approach concentrated on explaining the differences between the observed structure of single-surface bounce and double-surface bounce matched filter magnitudes. The results also indicated the best means of estimating the arrival time for the required ray path. These results were programmed into the ADAS. For the CEROS demonstration of the ADAS in May 2008, the ADAS only analyzed single-surface bounce ray paths and used the shortest arrival time of 11 pings over 30 s as the best arrival time estimate.

A paper detailing all the COTAPS technology was written and is to be published in the journal Ocean Engineering.

A second model study was initiated that deals with quantifying the impact of various surface wave affects on the arrival of single-surface bounce ray path that is first detected at a receiver. Observations collected during 2003 showed arrival time variations up to 6 ms over ~30 s intervals. Numerical experiments were performed to see if these variations could be accounted for by wave-induced background currents, the Doppler affect resulting from surface motion due to waves, and changes in path lengths due to sea level variations due to waves. Examples of the results are presented graphically in Fig. 1. For the 50m-50m-8km domain configuration (Fig. 1, left panel), the Doppler shifts are relative small (0.012 ms) and negative, the latter being the case for all the simulations. Also, the magnitudes of the differences between the model-predicted and flat surface ray path (FSRP) lengths and arrival times are quite small: ≤ 6 cm and < 0.06 ms, respectively.
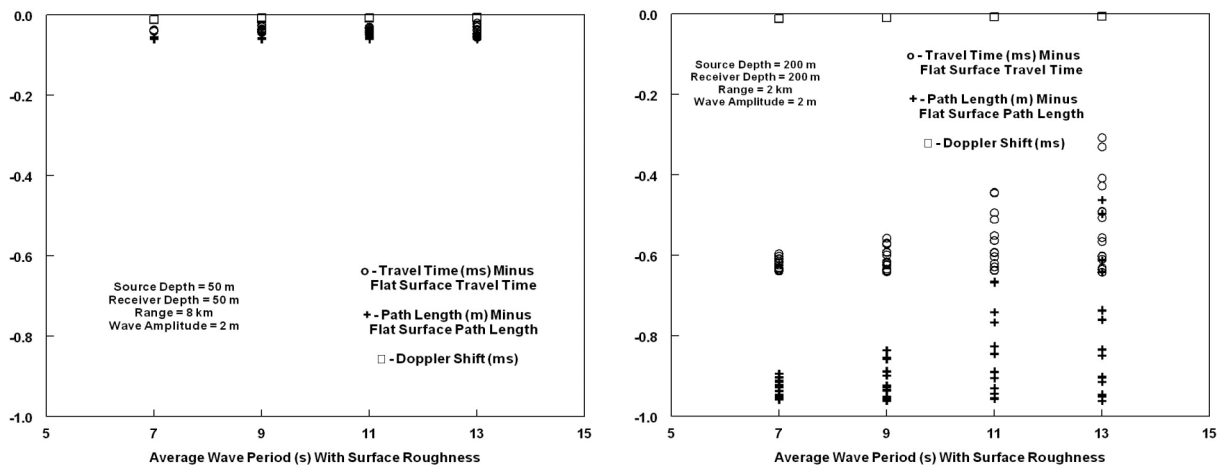

Fig. 1. Simulation results: 50 m source depth, 50 m receiver depth, and 8 km range domain configuration (left) and the 200 m source depth, 200 m receiver depth, and 8 km range domain configuration (right).

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For the 200m-200m-2km domain configuration (Fig. 1, right panel), we see again that the Doppler shifts are quite small. But the magnitudes of the differences between the model-predicted and FSRP path lengths and arrival times are now < 1 m and < 0.64 ms, respectively.

The model results indicate that the impact of the Doppler affect on calculating arrival times is always relatively small, with magnitudes always < 0.012 ms. The affect on arrival times due to wave-induced background currents can be as large as three times that of the Doppler affect.

A major conundrum is that the matched filter processing of the KauaiEx data gives typical variations in arrival times for 12 pings over ~30 s interval as 2-3 ms, not the order of < 1 ms as indicated by the simulations. And maximum variations for various KauaiEx source-receiver pairs range from 5.1 to 6.2 ms. Thus, the work indicates that the surface wave affects that we have modeled are not responsible for the arrival time variations observed during KauaiEx.

RESULTS

The modeling of multi-path signals generated by waves on the ocean surface has lead to a number of significant findings. The modeling deals with high-frequency tomography (> 3 kHz), with sound wavelengths considerably smaller than the lengths of the ocean surface waves between a source and a receiver. Under such conditions, the acoustic wave front from a single ping will be reflected toward the receiver at numerous locations along the ocean surface between the source and receiver. This model study showed that the assumption that the maximum matched filter magnitude is associated with the arrival time of the ray path required by COTAPS is only true for single-surface bounce ray paths. As a result, COTAPS now only uses single-surface bounce ray paths. The results also indicate that the best means of estimating the arrival time for the required ray path is the shortest arrival time out of 12-16 pings over ~30 s interval. For details, see Lewis, 2008, *J. Acoust. Soc. Am.*, 123(2), 878-886.

The results of the second model study deal with surface gravity waves with wavelengths at least 3-4 times larger than the acoustic wavelengths. The simulation experiments indicate that the Doppler affect has only a very limited impact on accurately estimating the arrival times of the acoustic paths used by COTAPS. The magnitude of the Doppler affect was found to be < 0.012 ms for the conditions that were simulated. We found that the impact of the wave-induced background currents could be up to three times greater than the Doppler affect, as larger as 0.035 ms. The largest impact on estimating the correct arrival time was the change in path length due to wave-induced sea level changes. The work suggests that the larger arrival time variations that were observed during KauaiEx in 2003 are a result of some phenomenon that occasionally masks ray paths between a source and receiver. Based on the numerical experiments and observations, a paradigm has been developed to best determine arrival times.

IMPACT/APPLICATIONS

We have made considerable progress in improving our knowledge base of acoustic propagation of ray paths from bottom-mounted sources and receivers. This is particularly true in our understanding of how surface waves impact the results of matched filter processing used by tomographic systems. Our published results will allow tomographers to better estimate ray path arrival times and assimilate the tomographic measurements into ocean models.

TRANSITIONS

None at this time, although a complete set of COTAPS software and hardware (a PC with the appropriate interface capabilities) is now available. This system is the ADAS developed under the CEROS contract to SSI and could be readily implemented at a Navy range, including the Pacific Missile Range Facility.

RELATED PROJECTS

Under funding from the Center of Excellence for Research in Ocean Sciences (CEROS), work was completed for designing and implementing an Acoustic Data Acquisition System (ADAS). This automated system executes on a PC to interface with a range's source-receiver control system. This ADAS specifies which projectors to send an acoustic signal to and which receivers to listen to. In addition, the ADAS processes the receiver data and calculates travel times based on the results of our ONR work. A test implementation and demonstration of the new ADAS was performed at the Pacific Missile Range Facility in May 2008.